# Appendix B - Cumulative Watershed Effects

Assumptions, procedures and caveats of the CWE analysis are described below. This analysis describes current watershed conditions as of February, 2000. Over time, model-generated values will change due to: (1) recovery of fire & harvest disturbances; road decommissioning, (2) refinement and/or update of component GIS layers [e.g., roads and harvest layers were updated in February, 2000], (3) refinements of coefficients [e.g., revision of mass-wasting coefficients as a result of flood assessment study done during the summer of 1998], (4) changes and/or refinement of models (e.g., adding complexity or simplifying).

**Landslide Model**

The landslide model estimates sediment production from mass-wasting. Results are based on the *Salmon Sub-basin Sediment Analysis,* (de la Fuente and Haessig 1993) and uses methodology developed in Amaranthus et al. [1985], the Grider EIS [1989] and the Forest Plan [1994]. The sediment study identified landslides and estimated landslide volumes based on air photo interpretation with some ground verification. Landslide prediction was based on actual landslide production for the period 1970 to 1975. Several large floods occurred in this time period but none as large as the 1964 flood. The coefficients, expressed as cubic yards per acre given a series of floods similar to the 1970 to 1975 period, are displayed in the following table.

Landslide Model Coefficients

| Geomorphic Type | Road Related | Harvest/Fire | | Undisturbed |
|---|---|---|---|---|
| | cu yd/ac | <20 years cu yd/ac | 20-40 yrs cu yd/ac | cu yd/ac |
| Active Landslides | 1,000 | 125 | 75 | 25 |
| Dormant Slides/Toe Zone | 225 | 3.2 | 3.0 | 2.8 |
| Granitic Mtn. Slopes >60% | 1,005 | 12 | 6.5 | 1.3 |
| Granitic Mtn. Slopes <60% | 36 | 11 | 5.9 | 0.6 |
| Non-Granitic Slopes >60% | 82 | 3.3 | 2.5 | 1.7 |
| Non-Granitic Slopes <60% | 19 | 2.1 | 1.2 | 0.3 |
| Unconsolidated Inner Gorge | 376 | 51 | 39 | 26 |
| Granitic Inner Gorge | 1,201 | 146 | 77 | 7.3 |
| Other Inner Gorge | 285 | 11 | 9.2 | 7.2 |
| Debris Basins | 25 | 50 | 3.8 | 1.3 |
| Glacial Moraine & Terraces | 7.5 | 6.5 | 4.9 | 3.2 |

To estimate future landslide production, the appropriate coefficient is multiplied by the acres of each geomorphic type by disturbance for each subwatershed. Background landslide production is based on the undisturbed landslide model coefficients and the acres of each geomorphic type.

**Surface Erosion Model**

Surface erosion modeling is based on the Universal Soil Loss Equation (USLE) which is A = RxLSxDx CxKxc. A is cubic yards per acre per year estimated sediment delivery to streams, R is rainfall/runoff factor; 28 for areas with greater than 60 inches precipitation/year, and 14 for areas with less than 60 inches precipitation/year)), LS is the length/slope factor (2.5 for gentle slopes, less than or equal to 35%, and 7.32 for steep slopes, greater than 35%), D is delivery ratio (.29 for road prisms, .05 for everything else), C is cover factor (.5 for roads, .06 for less than 10 year old plantations or fire, .01 for everything else), K is inherent soil erodibility from soils coverage, and c is 0.7 tons/cu yds conversion. Current surface erosion uses the acreage and coefficients for roads and 1988-1997 plantations and background surface erosion includes only the background coefficients.

Roads, plantations, wildfire, slope classes, geomorphic and soil types are Geographic Information System (GIS) layers. Variable road prism widths are used to convert road lengths to acreage. A road prism width of 12 meters or 39.17 feet was used for this model. This width was chosen for the following reasons: a) similar to the 40 foot width used in the Salmon ... Sediment Analysis [de la Fuente & Haessig, 1994] and the width on which mass-wasting coefficients were based; b) similar to 40 foot dominant road prism width determined in the Ishi Pishi Ecosystem Analysis by using a variable road width technique; c) similar to estimated road prism width of 37.88 foot computed for 16 foot average road width (14 foot travel surface plus average of 2 foot additional width for turnouts and turn widenings) on a 50% side slope [Harry Sampson, Forest Engineer; pers. comm., 1998].

Roads coverages encompass the entire analysis area, extending into non-KNFadministered lands and including roads under county, and private jurisdiction.

Through use of GIS, acres of different disturbance histories on different geomorphic and soil types, on different slope classes, and in different subwatersheds are generated and plugged into sediment modeling equations. The sediment model results are displayed in Step 5.

## Equivalent Roaded Area (ERA) Methodology

The ERA/TOC model provides a simplified accounting system for tracking disturbances that affect watershed processes, in particular, estimates in changes in peak runoff flows influenced by disturbance activities. Unlike the other two models discussed above, the ERA/TOC model is not intended to be a process-based sediment model. It does, however, provide an indicator of watershed conditions.

The ERA methodology is commonly used throughout the Forest Service Region 5 (California Region) for assessing Cumulative Watershed Effects. The basis for this methodology is converting road, harvest, fire, or other disturbance into Equivalent Roaded Area (ERA) using coefficients. The coefficients used for Thompson/Seiad/Grider are derived from the *Forest Plan*. Road miles are converted to acres as described under the sediment models. 0-20 year old regeneration harvest areas and 1987 moderate and high intensity wildfire acres are multiplied by 0.21 ERA/acre to convert to ERAs. 20-30 year old plantations are multiplied by 0.17 and 30-40 year old plantations are multiplied by 0.06 ERA/acre to convert to ERAs. The information needed to calculate ERA is in GIS and the percent ERA for each subwatershed is displayed in Step 5.

The percent ERA for each subwatershed is compared with a Threshold of Concern (TOC). The TOC is calculated based on the channel sensitivity (C), beneficial uses (B), soil erodibility (E), hydrologic response (H), and slope stability (S). The index for each of these factors is plugged into the equation - Watershed Sensitivity Level (WSL) = 3C + 2B + E + H + S. Watershed Sensitivity is converted to a Threshold of Concern in the equation - Threshold of Concern (TOC) = (43 - WSL)/2. The number "43" is used because it best fits a regression of the watershed sensitivity levels and previously determined Thresholds of Concern. For example, a watershed with sensitive channels, highly productive anadromous streams (high beneficial use), highly erodible soils, high landslide density &/or high percentage of granitic lands (slope stability), and high percentage of watershed in the ``rain-on-snow'' zone (~3,500' to 5,000' elevation; hydrologic response) would have a high ``Watershed Sensitivity Level'' and therefore a low TOC. The explanation and index value for each TOC parameter is discussed in the following paragraphs.

CHANNEL SENSITIVITY (C) is based on Pfankuch stream stability ratings or Rosgen channel types for each subwatershed.

| Parameter | Sensitivity Class | Index | Description |
|---|---|---|---|
| **Channel Sensitivity** | Very High | 5 | Pfankuch >130<br>Rosgen A4, B4, C4 |
| | High | 4 | Pfankuch 115-130<br>Rosgen A3, A5, B3, B5, C3 |
| | Moderate | 3 | Pfankuch 77-114<br>Rosgen B2, C1, C5 |
| | Low | 2 | Pfankuch 39-76<br>Rosgen A2, B1 |
| | Very Low | 1 | Pfankuch <39<br>Rosgen A1, F |

BENEFICIAL USE (B) is an index of the significance of the stream for beneficial uses, by the highest beneficial use of surface water. Five beneficial use stream classes are defined in the Forest Plan. A Class 1A stream is a highly productive anadromous stream, is a municipal or campground water source (>5 domestic uses), provides highly productive resident fisheries habitat, major fishing use, or major recreation use. Class 1B stream provides domestic use for 1-5 surface water users, moderately productive anadromous fisheries, or highly productive resident fisheries habitat with major fishing use. Class II provides agricultural or industrial use, low productivity anadromous fisheries, or moderately productive resident fisheries with moderate fishing or recreation. Class III provides low productivity resident habitat and is rarely used for fishing or recreation. Class IV provides no beneficial uses.

| Parameter | Significance Class | Index | Description |
|---|---|---|---|
| **Beneficial Use** | Very Highly | 5 | Class 1A. |
| | High | 4 | Class 1B. |
| | Moderate | 3 | Class II. |
| | Low | 2 | Class III. |
| | Other | 1 | Class IV. |

SOIL ERODIBILITY (E) is based on the relative proportions of soils with different inherent erosion potentials where:

Erodibility = [6(A + C) + 5(B + D) + 3(E + F + H) + 2(G + I) + J]/Watershed Acres; and A = acres of granitic soils, B & D = acres of metamorphic units on steep slopes, C = acres of mica schist, E = acres of dormant landslides, F = acres of shallow soil and rock outcrops, G = acres of very to extremely gravelly surface, H = acres of cobbly surface, I = acres of glacial till, and J = acres of all other units.

| Parameter | Sensitivity Class | Index | Erodibility Rating |
|---|---|---|---|
| **Soil Erodibility** | Very High | 5 | > 5 |
| | High | 4 | 4-5 |
| | Moderate | 3 | 3-4 |
| | Low | 2 | 1.3-3 |
| | Very Low | 1 | 1-1.3 |

HYDROLOGIC RESPONSE POTENTIAL (H) is based on the percent of the watershed in the transient snow zone (between 3,500 and 5,000 feet elevation), relative rain area (RRA or ratio of precipitation falling as rain vs. snow), and the dominant aspect of the watershed.

| Parameter | Peak Runoff Potential | Index | Description |
|---|---|---|---|
| **Hydrologic Response** | Very High | 4 | High risk for rain-on-snow event every 1-5 years, rain-on-snow zone > 1/2 watershed, RRA > 0.9, aspect S high, N low. |
| | High | 3 | Ocassional rain-on-snow event (5-10 years), 1/4 to 1/2 watershed in rain-on-snow zone, RRA 0.5-0.7. |
| | Moderate | 2 | Average risk of rain-on-snow event (10-25 years) <1/4 of the watershed in rain-on-snow zone, RRA 0.5-0.7. |
| | Low | 1 | Low risk of high runoff peaks, RRA < 0.5 |

SLOPE STABILITY (S) is based on the proportion of the watershed in various slope stability categories where

Stability Rating = [10A + 6B + 4(C + D) + 3E + F]/Watershed Area

A = acres of active landslide
B = acres of unconsolidated inner gorge
C = acres of consolidated inner gorge
D = acres on toe zones of dormant landslides
E = acres on highly dissected, steep granitics
F = acres of all other terranes

| Parameter | Risk Class | Index | Stability Rating |
|---|---|---|---|
| **Slope Stability** | Very High | 5 | > 1.5 |
| | High | 4 | 1 - 1.5 |
| | Moderate | 3 | 0.75 - 1 |
| | Low | 2 | 0.5 - 0.75 |

| | | | |
|---|---|---|---|
| | Very Low | 1 | <0.5 |

An ERA/TOC ratio of greater than 1.00 indicates that disturbance levels have exceeded the natural capacity of the watershed to ``absorb'' these disturbances. A basin is assumed to be healthy again as soon as sub-threshold ERA values are re-attained

## Model Integration

Cumulative watershed effects assessments should include consideration of all model results. Models were weighted equally, with one-third to the ERA/TOC model and two-thirds to the two sediment production models. Model-derived sediment production (in cy/ac/yr) from an Indian Creek CWE assessment and the Ishi-Pishi Ecosystem Analysis suggests that 75% of the total is from mass-wasting, with 25% from surface erosion. Therefore the mass-wasting model is weighted three times the surface erosion model. This yields a final weighting as follows: (1) ERA/TOC = 33.3%, (2) surface erosion = 16.7%, and (3) mass-wasting = 50%

Before applying the model weighting factors, individual watershed values were normalized by the following model ``threshold'' values: (1) ERA/TOC = 1.00, (2) surface erosion = 800% over background, and (3) mass-wasting = 200% over background, For example, a watershed with ERA/TOC = .80, surface erosion = 400%, and mass-wasting = 150% would have normalized values of ERA/TOC = .80 [.80/1.00], surface erosion = .50 [400%/800%], and mass-wasting = .75 [150%/200%].

Normalized and weighted values from the three models were added to yield the ``Combined'' watershed CWE index. The following table is a tabular summary of this procedure.

## Mathematics of Tools Used:

| | Mass Wasting | Surface Erosion | ERA/TOC | Combined Index |
|---|---|---|---|---|
| **Current** (total existing) | volume [C]; sed. prod. | volume [C]; sed. prod. | ERA | |
| **Background** | volume [B]; sed. prod. | volume [B]; sed. prod. | | |
| **Threshold** | 200 % | 800% | TOC | |
| **% Over Background** | **X** = (100) * [C - B] / B | **X** = (100) * [C - B] / B | risk ratio = ERA/TOC | |
| **% of Threshold** | **Y** = [X] / 2.0 | **Y** = [X] / 8.0 | **Y** = risk ratio / 1.0 | |
| **Model** | .50 (50%) | 0.167 | .333 | |

| | Mass Wasting | Surface Erosion | ERA/TOC | Combined Index |
|---|---|---|---|---|
| **Weighting Factor** | | (16.7%) | (33.3%) | |
| **Combination Index** | [Y] * [.50] | [Y] * [.167] | [Y] * [.333] | Sum of 3 values from left |